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Alaskan glaciers experienced rapid and accelerating wastage over the last 4-5 decades (Arendt and others, 2002) and accounted for 0.12 ± 0.02 mm/yr (or 7.5 %) of the total sea level rise between 1962-2006 (Berthier and others, 2010). Ice loss in Alaska is dominated by a few large glaciers located in the vicinity of the Gulf of Alaska (e.g., Columbia, Malaspina and Bering glaciers). Among them, the Bering Glacier System (BGS) is often regarded as the largest glacier system in North America with an area of nearly 4400 km^2 (Beedle and others, 2008) and over 5000 km^2 if the accumulation area of Tana glacier is included (Molnia, 2007).

The elevation change and volume loss of the BGS have been estimated by different authors using remote sensing techniques. They all used the 1972 United States Geological Survey (USGS) map as a reference topography. For a 2190 km^2 sub-area of the BGS, Arendt and others (2002) found mass loss of 2.3±0.5 km^3/yr water equivalent (w.e.) from 1972 to 2000. They carefully restricted their analysis to the lower part of Bering Glacier where they have flown airborne laser altimetry profiles in 1995 and 2000. Recently, Berthier and others (2010) estimated the mass loss of the complete BGS (following the definition of Beedle and others, 2008) as 2.6±0.5 km^3/yr w.e. by comparing recent (2003-2007) digital elevation models (DEM) derived from SPOT5 and ASTER satellite imagery with the National Elevation Dataset (NED) DEM derived from the 1972 topographic maps. Muskett and others (2009), M09 in the following, also compared recent (2000-2003) DEMs generated from airborne and spaceborne sensors to the 1972 map-derived DEM to estimate the total volume loss of a 3560 km^2 sub-area of the BGS. To be comparable to other estimates, we converted the M09 volume loss (191±17 km^3 or 6.2±0.5 km^3/yr) to mass loss, assuming a density of 900 kg m^{-3} for the material gain/loss by the BGS (the same assumption was used by Arendt and others (2002) and Berthier and others (2010)). Although measured during a similar time period the M09 mass loss, 5.6±0.5 km^3/yr w.e., is more than twice as large as other estimates (Arendt and others, 2002; Berthier et al. 2010). In this correspondence, we demonstrate that this discrepancy is due to overestimated volume loss by M09 for Tana Glacier and Bering Glacier Arm, a region that concentrate 60% (i.e. 114±4 km^3) of their overall BGS loss (their Table 2 and Figure 5). We also show that this overestimation originates from a vertically biased ASTER DEM.

We reproduced the M09 sequential DEM analysis for the Tana Glacier and Bering Glacier Arm by comparing the same original data: the 1972 USGS map-derived DEM and a pair of ASTER optical stereo images acquired 8 August 2003. Details on the methods we used to calibrate the USGS and ASTER DEMs can be found elsewhere (Berthier and others, 2010). Elevation changes during 1972-2003 are shown in Figure 1b for the whole ASTER scene. Only part of this map was used by M09 to measure volume changes (their Figure 5b) and it was not obvious to extract exactly the same sub-region as them (thick black polygon in our Figure 1b). Conservatively, we analyzed an area of 1112 km^2, which is larger than the 1015 km^2 area considered by M09. The glacier and nunatak outlines used here (Berthier and others, 2010) are different than those used by M09 and may explain part of this difference in areal extent. Over this 10% larger ice-covered area, the total volume loss is 28.6±5.5 km^3 (corresponding to an area-average thinning of 26±5 m), 4 times lower than the 114±4 km^3 volume loss reported by M09 (their Table 2).

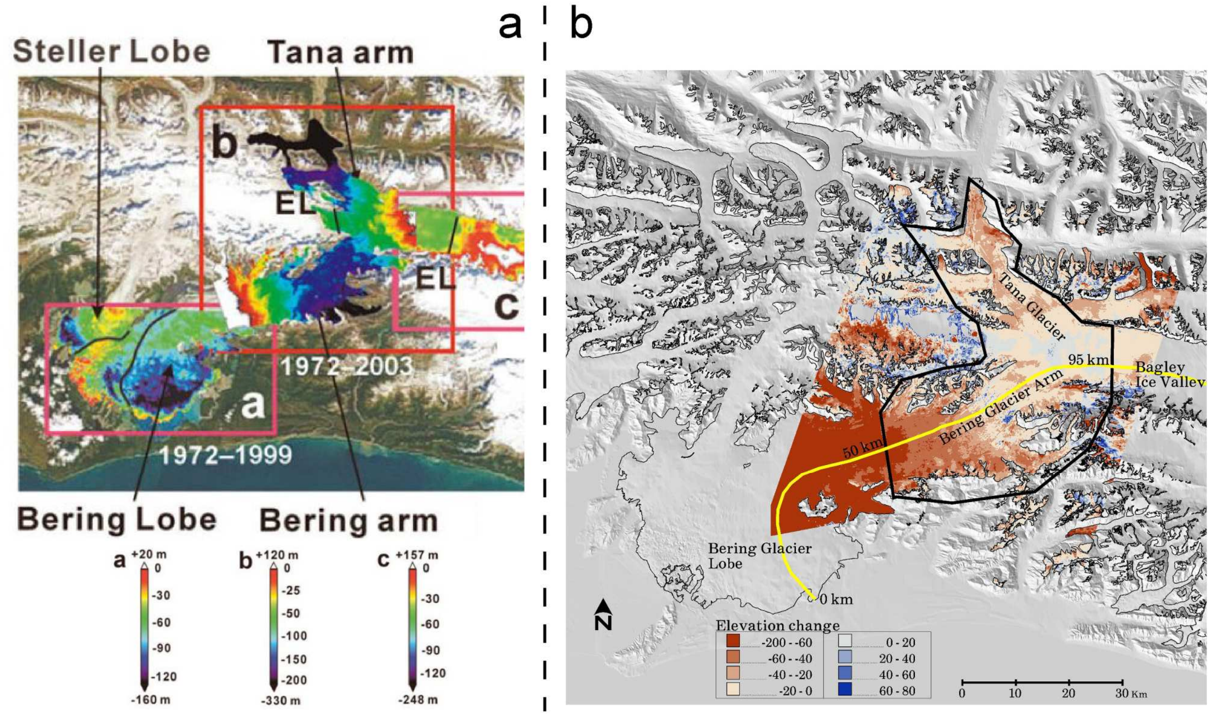

Figure 1: Elevation changes on the lower parts of Bering and Tana glaciers between 1972 and 2003; (a) reproduced from Figure 5 in M09 (see their legends for details); (b) calculated in this study. In the right panel, the background image is a shaded relief USGS DEM. The thin black line delimits the ice-covered areas extracted from the 1972 USGS maps (Berthier and others, 2010). The thick black polygon limits the area where volume change was derived by M09 using the ASTER-derived 2003 DEM. The yellow line locates the laser altimetry profile that was used by M09 in their Figure 6a. Distances along the laser altimetry profile are indicated.

There are several reasons why our new estimate for Tana Glacier and Bering Glacier Arm may be more reliable than M09's value:

(1) Our mean elevation difference between the ASTER and the USGS DEMs on the ice-free terrain is small, -1.4 m. The standard deviation of the elevation differences is relatively large (±30 m) but expected given the respective uncertainties of the USGS (±15 m) and the ASTER (±15-20 m) DEMs. M09 did not report those statistics on the ice-free terrain.

(2) Our ice elevation changes, shown in Figure 1, are consistent with the elevation changes measured by M09 using laser altimetry profiles along the Bering Glacier Arm (Figure 6a in M09). When projected in their figure 6a, the elevation changes derived from the ASTER DEM correspond to abscises 50 to 95 km. Our Figure 1 reveals the same pattern as the 1972-2003 curve in Figure 6a by M09, with thinning by 60-70 m in the lower part (abscise 50 km), evolving to no elevation change around abscise 85 km and then to slight thinning again at

higher elevations (abscise 95 km and further up in the Bagley Ice Valley). On the other hand, Figure 5b in M09 indicates strong thickening (120 m) in the lower part (abscise 50 km), then a maximum thinning of about 150 m and small thickening again at higher elevations (abscise 95 km). Thus, there are strong discrepancies between Figure 5b and 6a in M09. It is striking that the average thinning for Bering Glacier Arm and Tana Glacier derived by M09 using sequential DEM analysis, 112 m (Table 2 in M09), is higher than the maximum thinning they measured by differencing laser altimetry profiles and USGS DEM over the Bering Glacier Arm during the same time period (1972-2003).

(3) There are glaciologically unrealistic discontinuities in the different ice elevation change maps that were assembled from different elevation dataset by M09 (see the different panels in their Figure 5). At the transition between Bering Glacier Arm and Bering Glacier Lobe, there is a sharp shift from strong thickening (by about 120 m) to moderate thinning (by about 60 m). This vertical step (nearly 200 m) is located at the southwest boundary of their ASTER-based map of elevation changes. It cannot be explained by the 4-year difference between the two surveys (1972-2003 for the arm, 1972-1999 for the lobe) given that no surge is known to have affected the lower part of Bering Glacier between 1999 and 2003. Furthermore, neither a comprehensive map of ice elevation changes for the whole St Elias Mountains (Berthier and others, 2010, their supplementary Figure S1f) nor the laser-derived elevation changes (Figure 6a in M09) exhibit this vertical step but, instead, show a more or less regularly increasing thinning toward Bering Glacier Lobe. For similar reasons, the 60-70 m jump in the M09's elevation changes at the transition between Bering Glacier Arm and Bagley Ice Valley (which corresponds to the eastern boundaries of the ASTER-based elevation changes) is not glaciologically realistic. Here, the survey periods differ by three years: 1972-2003 for the Arm, 1972-2000 for the Bagley Ice Valley.

The facts that (i) these discontinuities are located at the edge of the ASTER DEM and (ii) that the accuracy of the other elevation datasets (Intermap DEM and SRTM DEM) used by M09 have been carefully examined, lead to the conclusion that a vertically distorted ASTER DEM is the source of these errors. The M09's ASTER DEM is too high in its eastern and western parts and too low in its central part. These deviations resemble a cylinder-shaped distortion of the geometric sensor model and subsequently of the DEM. Unfortunately, M09 did not describe their processing of the ASTER images, using the ENVI software. For example, it is not stated whether they used Ground Control Points. They simply indicated that it "*was adjusted using airborne laser altimetry acquired August 2003 for vertical bias control*". Thus, we cannot conclude on the origin of this vertical distortion in the ASTER DEM but we speculate that it was introduced during its adjustment to the laser altimetry data.

Due to errors during their processing of the ASTER DEM, M09 overestimated the volume loss for Bering Glacier Arm and Tana Glacier by about 85 km^3 (300% or 2.7 km^3/yr). The systematic errors that led to this overestimation were not included in their small error bar of ± 4km^3.

In a context of rapidly evolving ice masses, DEMs derived from satellite imagery are being increasingly used to monitor ice elevation changes on the outlet glaciers of the polar ice sheets (e.g., Stearns and Hamilton, 2007) or on mountain glaciers and ice caps (e.g., Berthier and others, 2004; Kääb, 2008). Those space-borne DEMs are now precise enough to measure the geodetic mass balance at the regional scale (Berthier and others, 2007; Paul and Haeberli, 2008) and thus, are useful (i) to complement the limited number of glaciers whose mass balances are monitored in the field, and (ii) to provide improved estimate of land ice contribution to sea level rise (Cogley, 2009). However, it is crucial that, first, the potential biases that can affect those DEMs are well understood and corrected. Visual verification that the pattern of ice elevation changes is consistent with glaciological knowledge is a first mean to detect some errors. Analysis of elevation changes on the ice-free terrain and direct comparison to contemporary elevation measurements obtained in the field (e.g., GPS) or from other space-borne platforms (e.g., ICESat) permit to detect and correct these biases.

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